The Application and Use of Microdrilling for Vertical Seismic Profiling and Monitoring Reservoir Performance

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RESEARCH OBJECTIVES

Microhole technology (providing inexpensive access to the subsurface) has the potential to be the most significant technology advance for the energy industry in the last 50 years. It has the potential to be a catalyst for creating a quantum leap in imaging technology, which could lead to a much clearer understanding of subsurface processes. A critical application is the placement of sensors in the subsurface for use with seismic techniques such as vertical seismic profiling (VSP), crosswell, microseismic, and even high-resolution surface seismic to image and monitor previously unknown or unresolved resources. To achieve this goal, we are pursuing an integrated program of testing, evaluation, and development of the technology required to deliver, process, and interpret the data.

APPROACH

The technology exists today to achieve many of these goals. To a large degree, it is a matter of tailoring this technology for the energy industry rather than starting from scratch. The DOE National Energy Technology Laboratory (NETL) oil program has undertaken and sponsored an integrated program of modeling, instrumentation evaluation/testing, and data acquisition and processing. This effort is tightly coupled with the microdrilling program at Los Alamos National Laboratory (LANL), and with field testing at the Rocky Mountain Oil Testing Center (RMOTC) at Teapot Dome in Wyoming (as well as at other sites of opportunity), to test and develop the technology. In the first year, the focus of the effort was modeling, design, and processing of multiple shallow VSP's (500 to 700 ft deep) in microdrilled holes within a well-characterized area. Follow-on tasks extended this work, with continued evaluation of sensors for use in microholes, optimizing the employment of sensors using innovative clamping and deployment mechanisms, partnering with industry for data acquisition and sensor evaluation, and processing/interpreting data derived from field tests.

ACCOMPLISHMENTS

In 2004 and early 2005, Berkeley Lab deployed a 20-level (with 5 m spacing) hydrophone and geophone string in the 750 ft deep microhole that LANL drilled at RMOTC. The purpose was to compare the difference between a fluid coupled sensor and a directly clamped sensor. The overall objective, however, was to determine the image volume and resolution that could be obtained from microholes drilled to depths above a target. For example, most VSP wells are drilled to the target or just above a target. In this case, our target was 1,500 ft (two well depths) below the well. Because of the small size of the microholes, a new type of clamping system had to be developed for the geophones. This "vacuum assisted" clamping mechanism is used to minimize the overall size of the package such that it will fit down the well. Another prime objective was to develop low-cost instrumentation that could be deployed in a low-cost manner (most VSP surveys cost from 50 K to 250 K per well to collect the data). Modeling of the shot-hole locations was performed prior to the field work to estimate shot spacing, total distance for the well, etc. Two complete VSP multi-offset (12 shot locations each) with offset distances from 35 ft to 2,700 ft (every 250 ft) were completed using a 20-level hydrophone string and a 20-level geophone string. In total, 40 levels were recorded for each set of sensors, using 12 different shot locations. A vibroseis was used as a source (Enviroseis from IVI Inc.) to minimize ground disturbance and maximize its high-frequency content (up to 300 Hz). Figure 1 shows one of the VSP results from the survey. As can be seen, the reflections are coming from well below the target depth. This was a relatively near offset, but it does show good reflections.

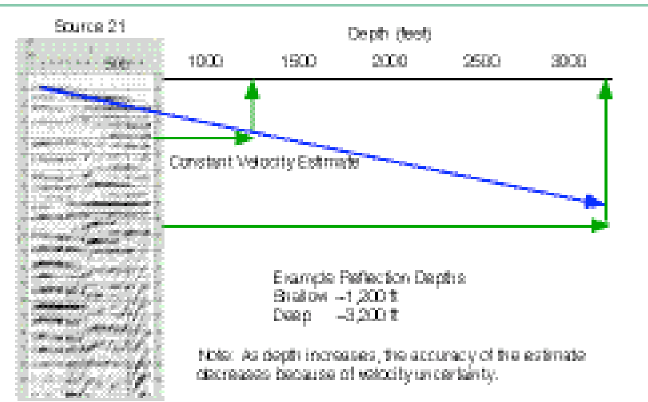

Figure 1. The estimate of the depth of reflections from the VSP in the 650 ft depth well; note the reflections at the 3,000 ft depth.

SIGNIFICANCE OF FINDINGS

All objectives were met in the evaluation of the microhole technology for VSP. In addition, a baseline study was obtained in preparation for future CO_2 injection monitoring. Direct arrivals were observable from source offsets of 2,800 ft, and reflections were observable as deep as 3,000 ft. As more microholes are drilled, additional data can be acquired to expand the image to accommodate larger CO_2 injections.

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